only its irritability but also its ability to remove itself from, or advance toward, the stimulus. Hence it will be able to conduct a stimulus received at one part to another part of the cell. It will be able to reproduce itself and give rise to new beings having similar structure and functions. The functions[3] of the cell have been classified as follows: *irritability*, *conductivity*, *contractility*, *metabolism*, and *reproduction*. These manifestations of life quite evenly distributed in simple cells become highly developed when specialization of the cell takes place.

Irritability.—Living protoplasm is able to receive stimuli; it possesses irritability. Dead cells are unable to receive stimulations, are unable to respond by any kind of action. Between these two extremes there are varying degrees of irritability. Some cells in the body are by nature more sensitive to stimuli than others (compare the skin of the finger-tip and the back of the arm, page 461). Also the normal irritability of certain cells may be greatly changed under conditions that favor disturbance in the normal functions of the body. Thus certain cells may be hypersensitive to stimuli (the nerve endings in the skin may be acutely irritable in certain conditions producing an extremely sensitive skin), and, on the other hand, cells may lose their irritability in part (the heart cells in certain conditions of disturbed internal secretions). This difference in irritability and the changes in irritability among cells are due to the physical and chemical constitution of the protoplasm of the cell at the particular time the stimulus is received.

Conductivity.—When a stimulus is received by a cell a reaction follows that is characteristic* of the cell in question. This reaction is carried throughout the cell and may even be conducted to neighboring cells. Nerve-cells show this quality in a very high degree.

Contractility.—The reaction to a stimulus is very frequently expressed as motion. Simple protoplasm shows to a marked degree the power of contractility. With the differentiation of cells in the multicellular animals there is a specialization in function so that some cells retain and develop to a higher degree certain powers originally possessed by all. Thus this power of contractility becomes associated with the differentiated muscle-cells; it is nearly lost in other than muscle-cells.

* Perhaps another quality should be introduced which might be called *correlation*. Thus a stimulus in one animal may produce one effect and in another a different one. What the effect may be is due to the physiochemic changes in the cells excited by the stimulus (see Forced Movements, Tropisms, and Animal Conduct, by J. Loeb, J. B. Lippincott Co., 1918).

Metabolism.—All cells possess the power to carry on the processes of life. These are in large part associated with taking certain energy materials and building them up in the protoplasm of the cell and removing the wastes that result from the activity of the cell. Metabolism consists in this dual process, the building-up phase of which is sometimes called *anabolism*, and the waste removal phase *catabolism*. Clearly, all cells carry on metabolic processes, but in the specialization of functions metabolic processes have been peculiarly taken over by the cells of the digestive tract, while other cells, the nerve-cells, for example, have very little metabolic activity.

Reproduction.—The biologist sees living forms as concerned only with the reproduction of their kind. Certainly this power possessed by very simple cells seems to be the end of life, the aim of all activity. Some cells multiply by merely dividing equally the protoplasm and nucleus; in others profound changes go on in which the nucleus is intricately involved. With the specialization of function the reproductive powers are taken over in man and certain other animals by a group of cells (sex cells) that are concerned only with this activity. Certain other cells in the body possess the ability to reproduce themselves (the cells of the skin do; nerve-cells do not), but the creation of a new individual is the work of the sex cells alone.

There are two methods by which cells divide and produce new individuals—the *direct* and *indirect*. The direct method of cell reproduction, called *amitosis*, takes place among the simplest forms of life, such as ameba. It consists in simple division of protoplasm and nucleus in which half of each part goes to the two cells resulting from the division. In complex forms, however, complicated nuclear changes are always apparent, and hence this indirect type, called *mitosis*, may be considered as applicable to man (Fig. 4). Details of this type are given in Chapter II.

Differentiation and Specialization.—By means of a power in the sex cell the new individual rapidly changes to a multicellular form. These changes will be described later. It is sufficient at this time to note that in this series of changes that occur there arises a differentiation in structure and a specialization in function which enables anatomists to group the cells of the body into particular classes, the classes of cells into tissues, the tissues into

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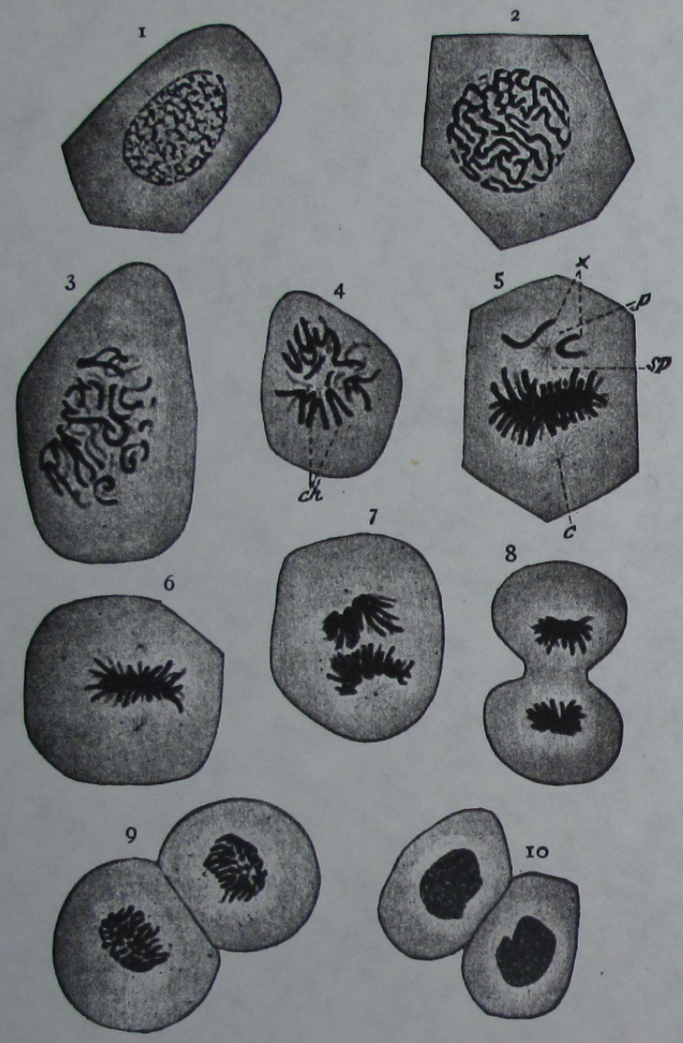

Fig. 4.—Ten stages of mitotic nuclear division from the oral epithelium of the larva of a salamander: 1, Cell with resting nucleus; 2, cell with nucleus at the beginning of mitosis; 3, nuclear membrane has disappeared, chromosomes in a loose skein, pole field at the left; 4, grouping of chromosomes into form known as monaster; 5, monaster viewed from the side, achromatic spindle is also shown; 6, monaster viewed from the side, with chromosomes crowded closely about the equator of the spindle; 7, middle stage; 8, beginning constriction of the cell body known as diaster stage; 9, regrouping of chromatic material with completion of the cell division; 10, final stage. (Sobotta and Huber's "Atlas and Epitome of Human Histology.")

organs, and the organs into systems. The sex cell has been metamorphosed. From one cell many different units have resulted, arranged in marvelous fashion to perform exceedingly intricate functions.

Organization of the Body.—As a result of differentiation and specialization the cells of the fully formed individual may be grouped into the following five classes, performing five functions:

1. *Epithelial* cells covering body surfaces, lining body cavities, and serving as the chief structural elements of all glands (Fig. 5).

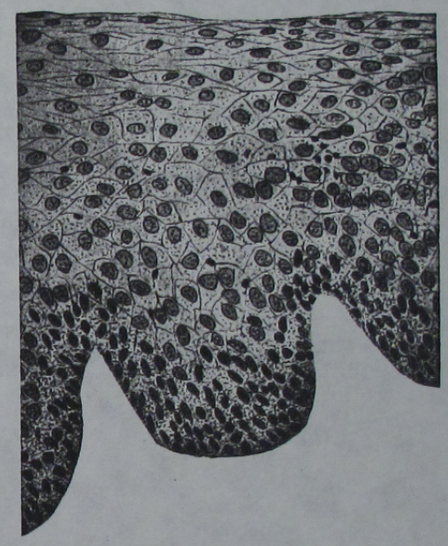

Fig. 5.—Cross-section of stratified squamous epithelium from the esophagus of man (Böhm, Davidoff, and Huber).

2. *Connective-tissue* cells forming the supporting, binding, and connecting parts for the other cells (Fig. 6).

3. *Muscle* cells providing contractile units for the body (Figs. 7–9).

4. *Blood* cells serving as transportation and protective agents for the body (Fig. 10).

5. *Nerve* cells acting as receiving and sending mechanisms (Fig. 11).

Groups of like cells bound together by an intercellular substance comprise a *tissue*. Thus a tissue is an aggregate of like cells, and they may be similarly classified into five groups:

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1, *Epithelial tissue;* 2, *connective tissue;* 3, *muscular tissue;* 4, *vascular tissue* (blood and lymph); 5, *nervous tissue.*

As a rule two or more tissues are arranged to perform a special function. Such an organization is called an *organ.* For example,

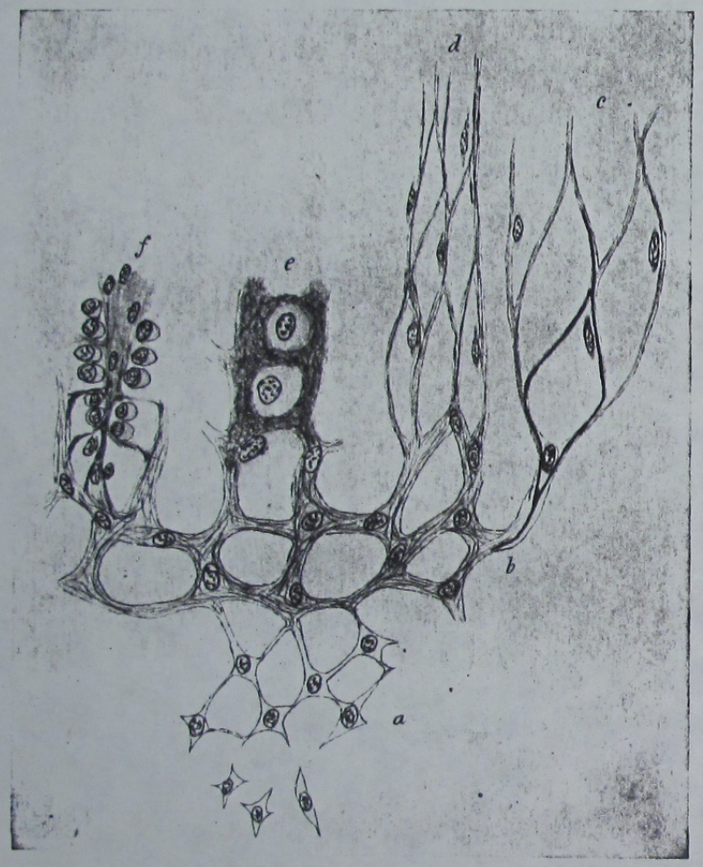

Fig. 6.—Schematic diagram given to show the development of the different types of connective tissue: *a*, Mesenchymal cells, certain of which are separate, others are joined by protoplasmic branches; *b*, syncytium with large strands of protoplasm and relatively few nuclei; *c*, reticular tissue—the dark fibers are elastic fibers; *d*, white fibrous tissue; *e*, cartilage; *f*, membranous bone. Note how well these cells are adapted for supporting and binding purposes. (Böhm, Davidoff, and Huber.)

the stomach is recognized as an organ. It is concerned with the function of receiving and digesting food. It is composed of all five tissues as, indeed, most organs are.

A further step in the organization of the body is the grouping together of several organs to accomplish a highly specialized piece of work in the body, as in a *system.* At times the organs composing a system are alike or very similar, *e. g.*, the muscles; at other

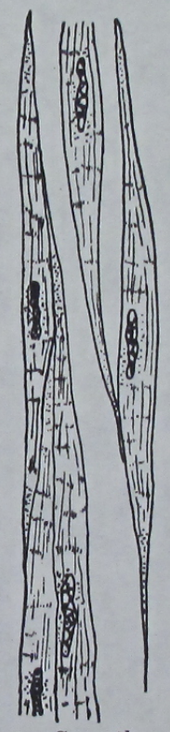

Fig. 7.—Smooth muscle cells, teased apart and showing long oval nuclei surrounded by undifferentiated protoplasm (Burton-Opitz).

Fig. 8.—Muscular fibers of the adductor magnus of a dog: *m*, Muscular fiber; *n*, nuclei; *s*, sarcolemma; *e*, *e*, spaces left by the retraction of the muscular substance from the interior of the sarcolemma. (Ranvier.)

times they vary widely, *e. g.*, the excretory system. The formation of a system has unity as regards function and represents, therefore, the tendency toward physiologic harmony. No matter how diverse the structure of the organs in a system, they are alike in

their co-operative endeavor to secure the special ends aimed at. There may be recognized nine systems in the body. These systems and the organs composing each are as follows:

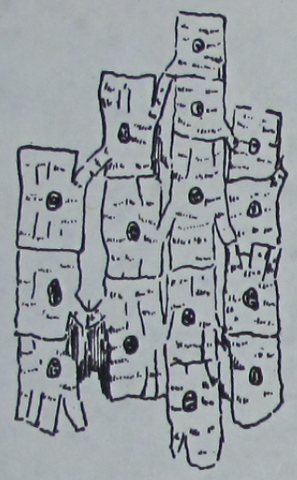

Fig. 9.—Cardiac muscle (Burton-Opitz).

1. The *skeletal* system comprises the bones of the skull, vertebral column, thorax, shoulder girdle, pelvis, upper and lower

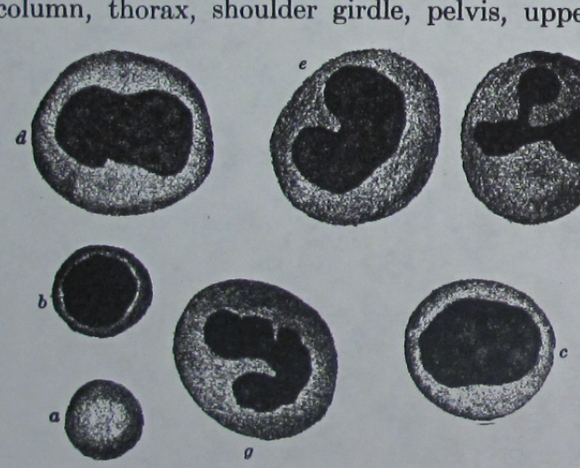

Fig. 10.—From the normal blood of man; × 1200 (from dry preparation of H. F. Müller): *a*, Red blood-cell; *b*, lymphocyte; *c* and *d*, mononuclear leukocytes; *e*, transitional leukocyte; *f* and *g*, leukocytes with polymorphous nuclei. (Böhm, Davidoff, and Huber.)

extremities. These bones are assembled in a definite order and are held together by ligaments.

2. The *muscular* system includes the muscles of the skeleton and the muscles of the blood-vessels and hollow organs (viscera).

3. The *digestive* system includes the teeth, salivary glands, esophagus, stomach, liver, gall-bladder, pancreas, small and large intestines.

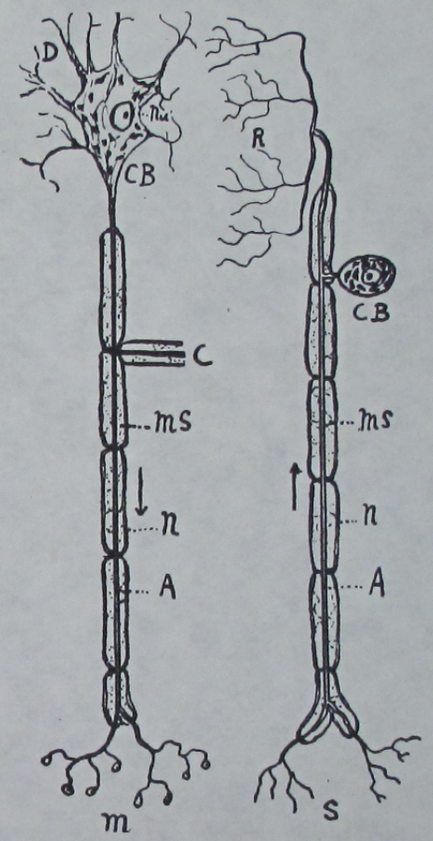

Fig. 11.—*M*, End-organ of efferent neuron; *S*, end-organ of afferent neuron; *A*, axon; *MS*, myelin sheath; *N*, neurilemma; *C*, colateral; *CB*, cell body; *D*, dendrites; *Nu*, nucleus and nucleolus; *R*, sensory terminals. (Burton-Opitz.)

4. The *respiratory* system comprises the nose, pharynx, larynx, trachea, bronchi, and lungs.

5. The *circulatory* system comprises the heart, blood-vessels, lymphatics, blood, and lymph.

6. The *excretory* system comprises the kidneys, ureters, bladder, urethra, and, in a limited sense, the skin and lungs.

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7. The *nervous* system comprises the brain, spinal cord, and peripheral nerves in the cerebrospinal system, and the chain of ganglia, plexuses, and nerves of the autonomic system.

8. The *reproductive* system comprises the ovaries, uterus, tubes, and the vagina in the female, and the testes, vas deferens, seminal vesicles, prostate, and urethra in the male.

9. The *endocrine* system comprises the thyroid, thymus, adrenals, pituitary body, pancreas in part, pineal gland, ovaries, and testes. The liver also acts as a gland of internal secretion.

This organization of the body provides in health a harmonious relationship between the different systems. High specialization demands co-operation, for the whole is dependent upon the parts.

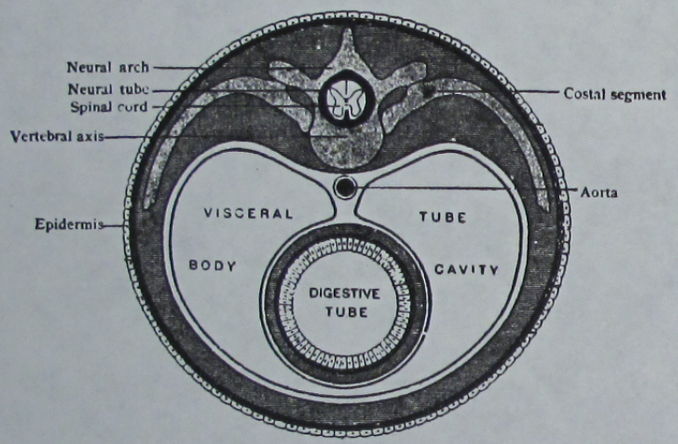

Fig. 12.—Diagrammatic plan of vertebrate body in transverse section (after Wiedersheim).

General Plan of the Human Body.—In the classification of animal life man is known as a vertebrate. In the group of vertebrates the characteristic structure is the possession of a spine or vertebral column, extending from the head to the tail end of the animal. Striking characteristics in the vertebrate plan are bilateral symmetry and body cavity formation. A transverse section (Fig. 12) of the plan of vertebrate body shows the symmetric arrangement, and a longitudinal section (Fig. 13) reveals the cavities.

The *dorsal cavity* is a single cavity with two well-defined divisions:

1. The cranial portion, in which lies the superior part of the nervous system, the brain, and

2. The spinal portion, in which lies the spinal cord.

The *ventral cavity* presents two well-defined divisions, completely closed to the outside (abdominal in the female excepted).

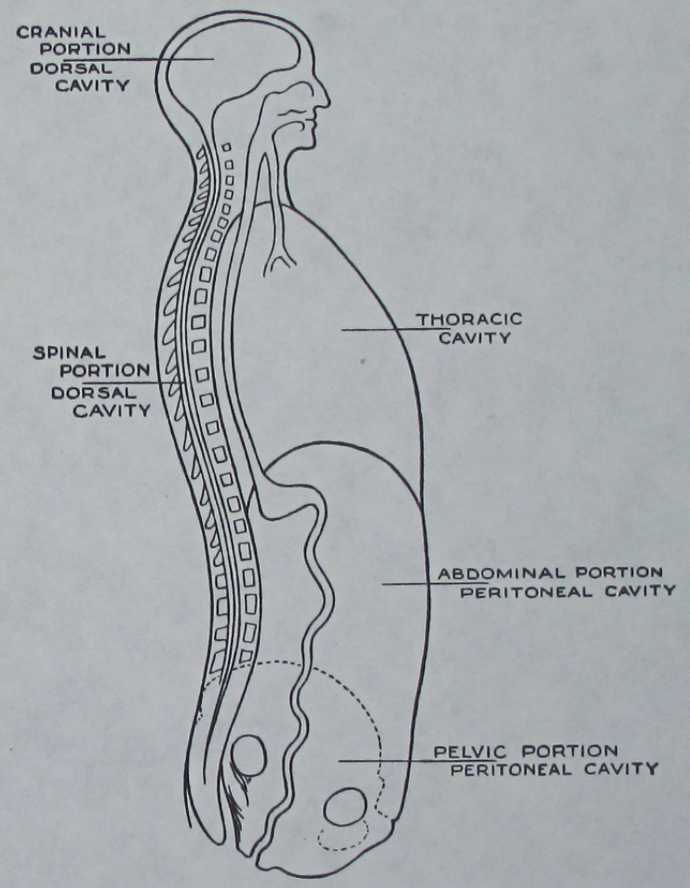

Fig. 13.—Diagram of the body cavities. The spaces indicated are not to be considered as empty. They exist only as potential cavities, but they are all closed (peritoneal in female excepted).

These cavities are the thoracic and peritoneal. They should not be confused with the lumina, or passages, or spaces in the respiratory or digestive tracts. The term "cavity" is used carelessly, *e. g.*, oral cavity, nasal cavity, orbital cavity, but such use is im-

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proper. Such passages are not to be classed with the cavities, which are true, closed spaces. However, in the female, the abdominal cavity is not closed because connection with the outside of the body is made via the vagina, uterus, and fallopian tubes.

1. The thoracic cavity is made up of the pericardial portion, in which is the heart and the beginning of the great vessels, and the pleural, in which are the trachea, esophagus, lungs, thymus, and adjacent arteries, veins, and lymphatics.

2. The peritoneal cavity has two divisions that are confluent and only defined artificially. The upper or abdominal portion contains stomach, liver, gall-bladder, spleen, pancreas, small and large intestine. The lower or pelvic portion contains the sigmoid, rectum, and bladder; in addition, in the female, uterus, tubes, and ovaries, and in the male, vas deferens, seminal vesicles, and prostate.

PRACTICAL EXERCISES

1. Study a one-cell organism. Paramecia may be secured from a hay infusion, which is made as follows: Obtain grasses from the side of a river or pond. Place grasses in a jar with water and set the jar in a light warm spot, preferably near a window. In several days small organisms can be collected from the scum that develops on top of the water. Place a drop of this material on a slide, cover with a cover-glass, and examine under the low power of the microscope.

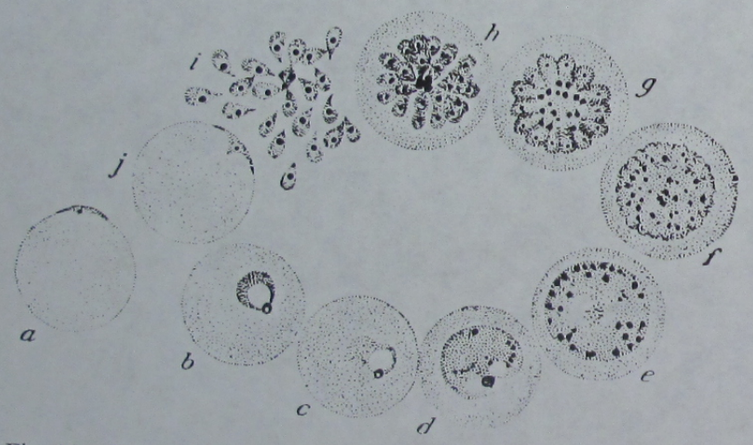

Fig. 14.—Reproduction of the malaria parasite in a red blood-cell: *a*, Entering the cell; *b*, within the cell; *c–h*, development and segmentation of the parasite; *i*, rupture of red cell setting young parasites free; *j*, one of them entering a red cell. The process goes on with continued destruction of the red blood corpuscles until the parasites are killed by medical treatment. (From Williams, Healthful Living, published by The Macmillan Company.)

2. Study slides* of the malarial parasite (Fig. 14).
3. Study slides of different bacteria.
4. Study slides of different types of cells, preferably of some showing the direct type of cell division.
5. Dissect a frog or larger animal and note tissues and organs. If a cat or a dog is dissected, the chief organs of the nine systems of the animal body may be studied.

QUESTIONS

1. Define the sagittal plane. Is the sagittal plane anteroposterior?
2. Locate the inferior eyelid, the lateral wall of the nasal cavity, the external surface of the teeth, the proximal end of the forearm, the peripheral portion of the ear, the mesial aspect of the arm, and the distal portion of the thumb.
3. What is irritability among cells? What is conductivity? Contractility? Metabolism? Reproduction?
4. Describe what is meant by differentiation and specialization.
5. Name the organs in the different body cavities. Do real cavities exist? What is a potential cavity? Does nature permit empty spaces to exist?
6. What is oxidation?
7. Name the systems of the body.
8. What are the five classes of tissues?

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* Permanent preparations of cells and tissues may be obtained from supply houses, such as Ward's Natural Science Establishment, Rochester, N. Y., and Marine Biological Laboratory, Woods Hole, Mass.

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